

EXHAUST GAS ANALYSIS FOR HARMFUL SPECIES: 19F1A FIRE FIGHTING TRAINER AT MAYPORT, FLORIDA

**Robert S. Levine
Kevin Greenaugh**

**U.S. DEPARTMENT OF COMMERCE
National Institute of Standards
and Technology
Center for Fire Research
Gaithersburg, MD 20899**

**Sponsored by:
Naval Training Systems Center
Orlando, Florida**

**U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
Dr. John W. Lyons, Director**

NIST

EXHAUST GAS ANALYSIS FOR HARMFUL SPECIES: 19F1A FIRE FIGHTING TRAINER AT MAYPORT, FLORIDA

**Robert S. Levine
Kevin Greenaugh**

**U.S. DEPARTMENT OF COMMERCE
National Institute of Standards
and Technology
Center for Fire Research
Gaithersburg, MD 20899**

**Sponsored by:
Naval Training Systems Center
Orlando, Florida**

May 1990



**U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
Dr. John W. Lyons, Director**

Table of Contents

	Page
Abstract	1
1. Summary	1
2. Discussion	1
2.1 Method	2
2.2 Groton Tests	3
2.3 Mayport Tests	4
2.4 Results and Conclusion	4
Appendix A. Report of Analysis - PAH's	9
Appendix B. Formal Report of Analysis for N-Nitroso Compounds	16
Appendix C. Smoke Analysis from 19F1A Trainer Bilge Fire Compartments	19

Exhaust Gas Analysis for Harmful Species - 19F1A Fire Fighting Trainer at Mayport, Florida

Robert S. Levine
Kevin Greenaugh
Center for Fire Research

Abstract

Gas sampling and subsequent analysis was carried out in a prototype Navy Firefighter Trainer to determine whether toxic species would be released to the environment by the Trainer. The Trainer uses propane gas for fires, and makes artificial smoke by vaporizing the smoke agent, butylated triphenyl phosphate, in hot air. There was concern that the smoke agent would react with the propane flame to form toxic products.

No evidence of reaction or toxic species beyond those to be expected from a clean propane flame was found

Key words: Toxic products; smoke; training devices; smoke production; chemical analysis; gas analysis.

1. Summary

Most of the chemical species of concern to the San Diego Air Pollution Control Agency were found to be not present in the exhaust gas from the 19F1A Bilge Fire compartment. A few chemical species were present in very small concentrations, but these same chemical species were generally present also in the background (no smoke or fire) samples taken from the bilge compartment.

It is concluded that there is no detectable chemical reaction between the smoke agent and the fire, hence no generation of carcinogenic or toxic species.

2. Discussion

The San Diego Air Pollution Control District in response to a Navy application (No. 880553) to construct a 19F5 fire Fighter Trainer at San Diego, imposed on June 5, 1989 a set of environmental conditions. One of these was that the ambient ground level concentrations of triphenyl phosphate (the smoke agent) not exceed 1.0 milligrams per cubic meter at any time.

In response to these, a meeting with the San Diego Air Pollution Control District personnel was held (August 8, 1989) to discuss them. The San Diego personnel, including Ms. Dede Ridenour and Mr. John McCafferty (Mr. McCafferty is the officer in charge of the 19F5 site permit), agreed with our finding that the smoke agent was of low toxicity, but pointed out that we had no information on whether toxic species would be formed when the smoke agent contacted the propane fires in the trainers. This was the reason for the severe criterion on triphenyl phosphate content in the air outside the trainer.

Although stack dispersion calculations (using equations in Marks Mechanical Engineering Handbook) indicate the criterion can be met, the Naval Training Equipment Center requested an analysis/investigation to:

1. Determine if any toxic species are created in the operating trainers.
2. Obtain a justification to request substantial relaxation of the 1 mg/m^3 requirement. This would lessen the requirement for the Navy to carry out periodic sampling and analyses to insure compliance.

As a result of subsequent telephone conversations with Mr. McCafferty, a list of the chemical species of most concern to his agency was made available to the Center for Fire Research. These are listed in the first column of Table 1. The meanings of the other columns of Table 1 are described below in the text.

2.1 Method

While we were at the San Diego Air Pollution Control Agency we were given a copy of their publication 2.0.7, "Test Methods with Outline of Calculations." After reviewing their publication, personnel from the Center for Analytical Chemistry at the National Institute of Standards and Technology recommended that we use a resin called XAD-2 (purified by extraction with chromatography grade dichloromethane) for the PAH (polycyclic aromatic hydrocarbons) samples instead of the method in the publication. In a telephone conversation, Ms. Ridenour agreed, provided we use the methodology being developed by Mr. Peter Ouchida of the California Air Resources Board, Sacramento. Mr. Ouchida's recommendations (their method 429, September 12, 1989) include:

1. Teflon¹ tubing (short lengths) to connect pieces. All tubing was cleaned with acetone and methyl alcohol.

¹ Certain commercial equipment, instruments, or materials are identified in this paper to adequately specify the experimental procedure. This does not imply recommendation or endorsement by NIST or that the material or equipment identified are necessarily the best available for the purpose.

2. Teflon filter for particulates and species adsorbed on them. (Sample #1 for PAH analysis). We used a Teflon size 47 filter which was ultrasonically treated with dichloromethane prior to use.
3. Amberlite XAD-2 Resin - (we used Supelpak-2, which is XAD-2 purified by the manufacturer). This is Sample #2.
4. Sample train (apparatus) at room temperature. Keep samples on dry ice until analysis. (We kept samples on water ice until returned to NIST. Dry ice was not available in the field.)
5. Obtain blanks (repeat experiment with fire and smoke off).
6. Nitrosamines - use Thermetics Lab Samplers, which have a preliminary bed that prevents artifacts that might be formed from nitrogen oxides or nitric acid. (We did.)
7. Isokinetic sampling. (Same velocity through probe orifice as the duct velocity.) We couldn't do this. Our duct velocity was too high to be compatible with a sample flow of 200 cc/min. and a reasonable probe hole size. This means our sample probe engulfed a somewhat higher proportion of particulates than that in the exhaust.
8. Quartz or Pyrex sample probe and cartridges. Stainless steel is not acceptable for PAH's.

A sketch of the sampling assembly is shown as Figure 1.

In addition to the XAD-2 resin samples and the nitrosamine cartridges, samples and backgrounds (blanks) were taken in tubes filled with Tenax adsorbent, and were analyzed by the "Indoor Air Quality" group in the NIST Center for Building Technology. The sample tubes were also prepared and conditioned for us by that unit. They analyzed the results with a gas chromatograph - mass spectrometer technique whereby a computer used with the machine looks for matches with the peaks from known chemicals. If it sees, say 80% of those peaks, it reports the presence of that species at a calculated probability. We depend on this analysis for the remaining species on the San Diego APCD list. The benzene threshold concentration detectable by this procedure as run is 4.2 micrograms per cubic meter, and the sensitivity for other species is comparable.

2.2 Groton Tests

Tests were run with the hull fire of the 21C12 submarine trainer at Groton, CT, and above the bilge fire compartment of the 19F1A advanced trainer at Fleet Naval Training Center, Mayport, Florida. The Groton tests turned out to be a rehearsal. Two major things were wrong:

1. We didn't have Teflon tubing yet, so we used Tygon tubing.
2. We didn't take the blanks (background samples) first.

Sampling in the 21C12 was done at the entrance to the exhaust duct in the overhead of the training compartment. Thermocouple data indicated the air temperature there would not be too high for the

equipment, and the sample tubes were kept cool by insulation and ice water. However, thermal radiation from the ceramic insulation above the fireplace overheated the tygon tubing; and eventually destroyed the filter holder. So we had contaminated samples, and were unable to get blanks.

The resulting "air quality unit" analysis is included here, however, as part of Appendix C (Page 20) because it shows many of the species to which the analysis method is sensitive. According to Air Quality Unit personnel, most were created by decomposing tygon tubing in the equipment. The subsequent work at Mayport saw few of these species, so their absence in the Mayport results confirms they really were not present.

The nitrosamine cartridges were analyzed by the vendor, Thermetics Laboratories, Inc. No nitrosamines were present.

The Groton results are indicated in column 2 of Table 1.

The PAH sample was not analyzed. It was meaningless without the blank. (PAH's are probably ubiquitous in the winter (home heating) air at Groton.)

2.3 Mayport Tests

At Mayport the sampling was done with the probe inserted through a hole in the ventilating duct above the propeller shaft bilge fireplace, as the duct passes through the crawl space to the upper floor. A photograph of this location is shown in Figure 2. Note the location is cool, clean, and spacious, permitting easy manipulation of the equipment.

The blanks were taken first, with the ventilation fan running, with no "smoke" or fire. After the blanks were taken (a period of perhaps 15 minutes) we observed a light coating of smoke particulate on the upstream edges of the probe. This was undoubtedly due to smoke leakage from another compartment of the trainer where work was being done. However, because the leakage was slight, we concluded that whatever contamination was found on the blanks would be trivial compared with the operational samples.

All sampling was done at a flow rate of 200 cc/min through the apparatus for 3 minutes per sample or blank. This was measured with a rotameter at room temperature in the suction pump line of our instrument van. In prior work we found that the filter in the sample train did not develop significant pressure drop with less than 15 minutes of flow, so we are confident that the pressure at the rotameter was very close to atmospheric.

2.4 Results and Conclusion

The report of the PAH analysis is presented as Appendix A of this memorandum, the nitrosamine analysis as Appendix B, and the "indoor air quality" analysis as Appendix C. See comments on the results of the latter analysis on pages 19 and 20 (Appendix C). The salient data are recorded in Table 1, column 3. It is seen that to a sensitivity of about 10 micrograms per cubic meter, the trainer generated no open PAH's (apparently both the sample tube and the blank were slightly contaminat-

ed). Nitrosamines were also absent. Only traces of other species, which could be anticipated in a propane turbulent diffusion flame were found. The samples tested showed no generation of a toxic hazard, and no indication of reaction of the smoke agent in the flames.

Table I. Chemical Species of Concern to the San Diego Air Pollution Control District

Species	Results of Analysis		
	Groton Samples	Mayport Results	Remarks
polynuclear aromatic hydrocarbons (PAH)	not analyzed	4 PAH's detected on filter but in similar amount in blank. 14 PAH's not present in adsorbent tubes.	No PAH's generated in the facility
Nitrosamines dimethylnitrosamine dimethylnitrosamine dibutylnitrosamine	none none none	none none none	No nitrosamines generated in the facility
Acetaldehyde	70% probable	78% probable	
Acrylonitrile	—	—	(a)
Benzene	92% probable	89% probable	Traces of benzene are made in sooting turbulent diffusion flames
Benzidine	—	—	(a)
Benzo(a)pyrene	—	not present	See PAH analysis
1-3 Butadiene	89% probable	not present	
Diphenyl hydrazine	—	—	(a)
Ethylene oxide	—	—	Would have to be made from ethanol, which is a trace constituent
Formaldehyde	—	—	
Propylene oxide	—	—	
1,4 -Dioxane	—	—	
Ammonia	—	—	(a)
Arsine	—	—	(b)
Chlorine	—	—	(c)
Cresols	86% probable	not present	
Nitric acid	—	—	(a)
Nitrobenzene	—	—	(a)
Phosgene	—	—	(c)
Phosphine	—	—	This is an oxidizing atmosphere. If the smoke agent reacted, phosphorous oxide would form. See Note (d)
a. No bound nitrogen in the reactants, so we would not expect these species could be formed. b. No arsenic in the reactants, so it is impossible to form this. c. No chlorine in the reactants, so it is impossible to form this. d. No combustion of the smoke agent occurred in a smoke generator malfunction where fire contacted atomized smoke agent - no phosphorus oxide in the metal slag. So we would not anticipate phosphorus compounds here. Also, phosphine, if formed, would quickly burn to phosphorus oxide.			

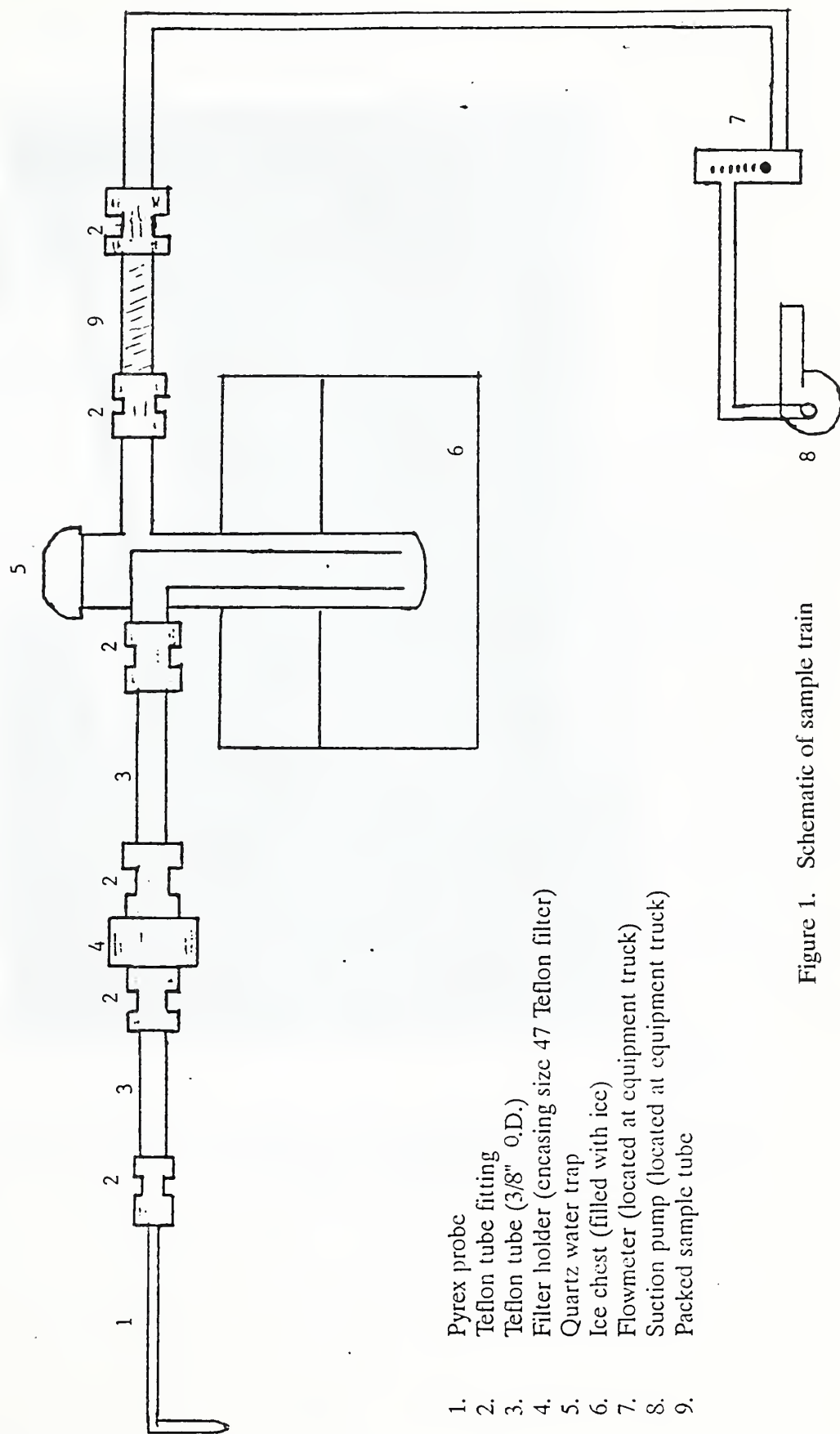


Figure 1. Schematic of sample train

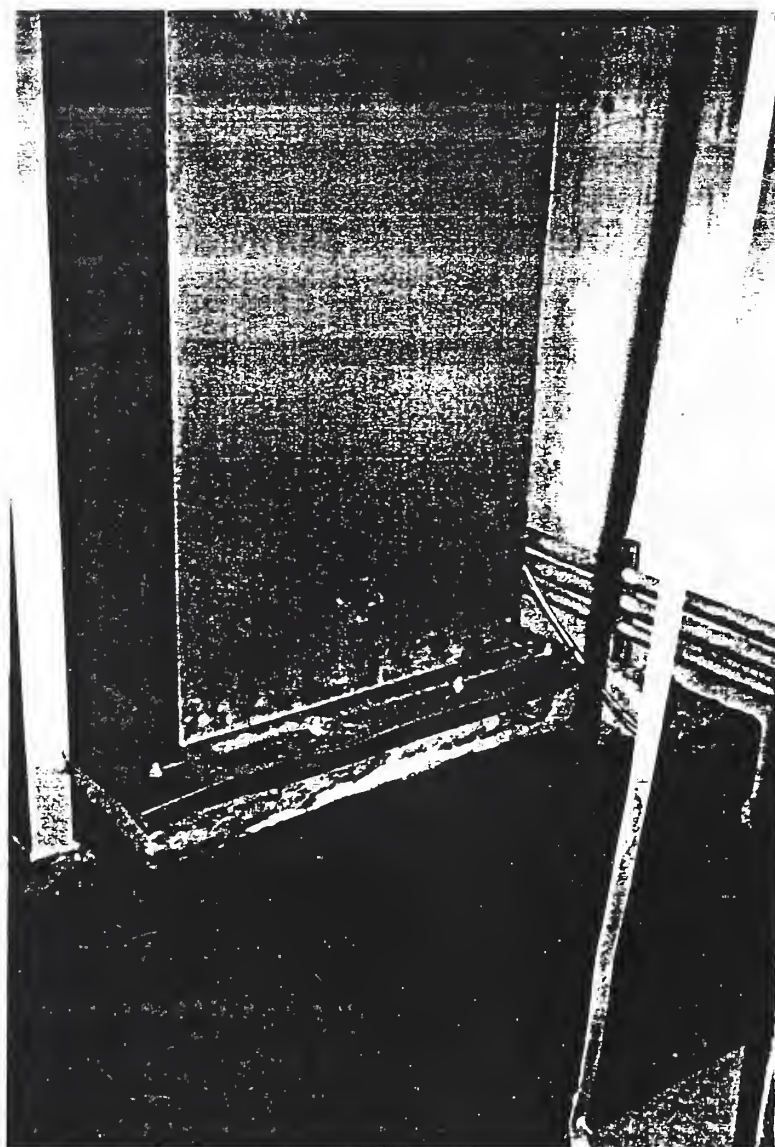


Figure 2. Gas sample location in the exhaust duct above the "Shaft-Bilge" fire site, 19F1A Trainer at Mayport



Appendix A. Report of Analysis - PAH's

January 16, 1990

Dr. Robert S. Levine
Center for Fire Research
NIST

Dear Bob:

Please find enclosed a Report of Analysis for the XAD and filter samples you submitted to us for measurement of polycyclic aromatic hydrocarbons (PAHs). Some of the PAHs were detected on the XAD and the filter blanks. Detection limits were estimated for species not observed in the blanks or samples. Should you have any questions about the method or the results, please contact me at the phone number below.

Sincerely,

Bruce A. Benner, Jr.

Bruce A. Benner, Jr., Ph.D.
Research Chemist
Organic Analytical Research Division
Center for Analytical Chemistry
(301) 975-3113

enclosure

552-90-009

REPORT OF ANALYSIS

Analysis of Vapor and Particle Phase Air Samples Collected at a Naval
Fire Training Facility

Submitted to:

Robert S. Levine
Center for Fire Research

INTRODUCTION

Two vapor and particle phase air samples (including 1 blank for each phase) were collected at a naval fire training facility (Mayport, FL) by R. S. Levine (CFR) and submitted for determination of polycyclic aromatic hydrocarbons (PAHs). The facility uses a hydraulic fluid, butylated triphenylphosphate, to generate a white smoke used in fire training exercises. There was concern that the process used in generating the "training smoke" would also produce PAHs, some of which have been shown to be mutagenic in bioassays.

EXPERIMENTAL SECTION

Sample Collection. One 45 mm (diam.) Teflon-coated glass fiber filter collected a particle phase sample and one 6 mm (i.d.) x 15 cm glass tube packed with two separate sections of a pre-cleaned XAD porous-polymer resin collected a vapor phase sample. The downstream section of XAD would collect species not retained by the first XAD section. The presence of a particular compound on the downstream XAD section would suggest incomplete collection of that compound (breakthrough). The particle and vapor phase samples were collected at a flow rate of 200 mL/min for 3 min (total volume of 600 mL = $6.0 \times 10^{-4} \text{ m}^3$). A blank filter and XAD tube were also supplied for analysis and were generated by sampling the air with no training smoke being generated.

Sample Extraction. The filter sample and blank were each placed in 150 mL beakers to which were added 20 mL of dichloromethane and 1 mL of a deuterated-PAH internal standard solution. The filters were then ultrasonically extracted for 3 min, concentrated under N_2 to < 2 mL and filtered through 13 mm diam. (0.45 μm pore size) fluoropolymer filters into 0.1 mL conical vials. The extracts were further concentrated under N_2 to approximately 50 μL . The blank and sample XAD tubes were scored and broken between the two sections of resin and each section (primary and backup) was transferred to separate 50 mL centrifuge tubes. The resins were then spiked with 50 μL of the same deuterated PAH standard as the filters, ultrasonically extracted with two 10 mL volumes of DCM (1 min each), concentrated under N_2 to < 0.5 mL and filtered through the 13 mm (diam.) fluoropolymer filters (0.45 μm pore size) into 0.1 mL conical vials.

GC-MS Analysis. Both the filter and XAD samples were analyzed using the same GC-MS method. Approximately 1 μ L volumes of the sample extracts were manually injected directly onto the 0.25 mm x 60 m column (DB-5, 0.25 μ m phase thickness). Helium was used as the carrier gas at a head pressure of 25 psi, with an auxiliary flow of 1 - 2 mL/min. The column temperature program began at an initial temperature of 37 °C followed by a rapid heating (30 °C/min) to 100 °C, and a gradual increase (2 °C/min) to the final temperature of 300 °C. The GC-MS interface temperature was maintained at 300 °C. The mass spectrometer was operated in the selected-ion monitoring mode described in detail below:

<u>Time period (min)</u>	<u>Masses monitored (amu)</u>	<u>Target PAH</u>
10 - 20	128, 136	naphthalene
20 - 44	154, 164, 166	biphenyl, acenaphthene, fluorene
44 - 50	178, 188	phenanthrene and anthracene
50 - 58	192, 206	alkyl phenanthrenes
58 - 72	202, 212	fluoranthene and pyrene
72 - 82	228, 240	benz[a]anthracene and chrysene
82 - 100	252, 264	benzofluoranthenes and benzopyrenes
100 - 130	276, 288	indeno[1,2,3-cd]pyrene and benzo[ghi]perylene.

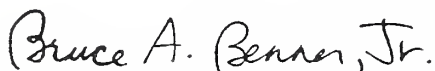
Results and Discussion. Both segments (primary and backup) of the blank and sample XAD sorbents showed responses for naphthalene (128 amu, 14.4 min), phenanthrene (178 amu, 46.6 min) and for an alkylphenanthrene species (206 amu, 57.3 min). Blank and sample XAD extracts also showed response for 166 amu (43.0 min), that was not fluorene (different retention time). Little can be said of the concentrations of these PAHs since they were detected on both the primary and backup sections of both the blank and sample XAD sorbents. For those species not detected on either the primary or backup XAD sections, detection limits were estimated considering a minimum peak area of 50,000 counts, the 600 mL sampling volume and linear responses for PAHs measured in the standard solution (see Table 1).

Both the blank and sample filter extracts gave similar responses for fluorene, phenanthrene, methylphenanthrenes, dimethylphenanthrenes, fluoranthene, pyrene, and an unknown species with a 228 amu ion. These results suggest that the blank may have been contaminated, or that the blank was influenced by other training fires using the same ventilation system at the facility. The blank and sample concentrations of these PAHs are so similar as to preclude "blank subtraction" from the sample concentrations (see Table 2). The estimated detection limits for PAHs not observed in the blank and sample filter extracts, using the same criteria as described above, are shown in Table 3.

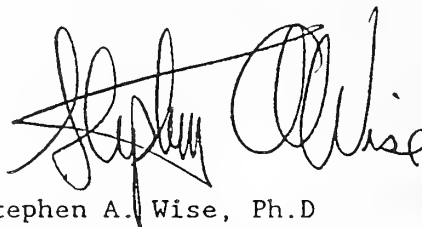
Conclusions. In both the particle (Teflon filters) and vapor phase (XAD sorbent tubes) sampling of the artificial smoke, the samples proved to be insignificantly different from the respective blanks. One limitation of this study may have been the relatively small sampling volumes (6.0×10^{-4} m³) used

in collecting the samples. Had the sampling proceeded for 30 min instead of 3 min, the detection limits stated in Tables 1 and 3, would have been a factor of 10 lower. This would have resulted in detection limits of less than 1 $\mu\text{g}/\text{m}^3$ for most of the PAHs considered in this study.

Data supporting this report can be found in B. Benner's laboratory notebook BAB V, pages 21-26.



Bruce A. Benner, Jr., Ph.D
Research Chemist
Organic Analytical Research Division
Center for Analytical Chemistry



Stephen A. Wise, Ph.D
Supervisory Research Chemist
Organic Analytical Research Division
Center for Analytical Chemistry



Willie E. May, Ph.D
Division Chief
Organic Analytical Research Division
Center for Analytical Chemistry

Table A1. PAHs not Detected on XAD Sorbent Tubes after Sampling
at Naval Fire Training Facility

<u>Compound</u>	<u>Detection Limit ($\mu\text{g}/\text{m}^3$)</u>
acenaphthene	9
fluorene	15
1-methylphenanthrene	13
fluoranthene	7
pyrene	7
benz[a]anthracene	7
chrysene/triphenylene	7
benzo[b]fluoranthene	7
benzo[k]fluoranthene	6
benzo[e]pyrene	6
benzo[a]pyrene	7
perylene	8
indeno[1,2,3-cd]pyrene	6
benzo[ghi]perylene	5

Table A2. PAHs Detected on Teflon Filters after Sampling
at Naval Fire Training Facility^a

<u>Compound</u>	<u>($\mu\text{g}/\text{m}^3$)</u>	
	<u>Filter Blank</u>	<u>Filter T1A</u>
fluorene	10.2 ± 1.4	13.5 ± 1.9
phenanthrene	4.5 ± 0.6	5.0 ± 0.7
fluoranthene	1.6 ± 0.2	2.7 ± 0.4
pyrene	1.6 ± 0.2	2.8 ± 0.4

^a Uncertainties represent propagation of a 10 % error in the analytical and sample volume measurements.

Table A3. PAHs not Detected on Teflon Filters after Sampling
at Naval Fire Training Facility

<u>Compound</u>	<u>Detection Limit ($\mu\text{g}/\text{m}^3$)</u>
naphthalene	4
acenaphthene	9
benz[a]anthracene	7
chrysene/triphenylene	7
benzo[b]fluoranthene	7
benzo[k]fluoranthene	6
benzo[e]pyrene	6
benzo[a]pyrene	7
perylene	8
indeno[1,2,3-cd]pyrene	6
benzo[ghi]perylene	5

Analytical Services Laboratory

470 Wildwood Street
P. O. Box 2999
Woburn, MA 01888-1799
(617) 938-3786

Telex: 92-3473

**FORMAL REPORT OF ANALYSIS
FOR
N-NITROSO COMPOUNDS**

Prepared for:

National Inst of Standards & Technology
Bldg 301 Receiving Room
Rt 270 and Quince Orchard Rd.
Gaithersburg, MD 20899

Attn: P.O. 40NANB0 07269

Date:

January 16, 1990

Report No.:

5450-5748

Notebook Page:

249-36

Approved by: _____

William Ziff

Thermedics Inc.

SUMMARY OF RESULTS

Thermosorbs

Customer Sample Number	Air Volume Liters	NMA ¹ ₃ ug/m ³	NDEA ¹ ₃ ug/m ³	NDPA ¹ ₃ ug/m ³	NDBA ¹ ₃ ug/m ³	NPiP ¹ ₃ ug/m ³	NPYR ¹ ₃ ug/m ³
A24156	600	___2	___2	___2	___2	___2	___2
A24166	600	___2	___2	___2	___2	___2	___2

1. N-nitroso compounds in micrograms per cubic meter.

2. Not detected.

Limit of detection:

(for a 100 liter sample) 0.05 ug/m³ for NDMA
0.08 ug/m³ for NDEA, NDPA, NPiP, NPYR, and NMOR
0.10 ug/m³ for NDBA

Date Sample Received: 12/20/89

Date of Analysis: 1/5/90

Method of Analysis: GC-TEA

ABBREVIATIONS

NDMA - N-nitrosodimethylamine
NDEA - N-nitrosodiethylamine
NDPA - N-nitrosodipropylamine
NDBA - N-nitrosodibutylamine
NP1P - N-nitrosopiperidine
NPYR - N-nitrosopyrrolidine
NMOR - N-nitrosomorpholine
NMVA - N-nitrosomethylvinylamine
NMEA - N-nitrosomethyl ethylamine
NEPA - N-nitrosoethylpropylamine
NPBA - N-nitrosopropylbutylamine
MPA - N-nitrosomethylpropylamine
NMBA - N-nitrosomethylbutylamine
NEBA - N-nitrosoethylbutylamine
NMBZA - N-nitrosomethylbenzylamine
NPBZA - N-nitrosophenylbenzylamine
NDAA - N-nitrosodiamylamine
NDCHA - N-nitrosodicyclohexylamine
NDPHA - N-nitrosodiphenylamine
NMDDA - N-nitrosomethyldodecylamine
NMTDA - N-nitrosomethyltetradecylamine
NMPHA - N-nitrosomethylphenylamine
NEPHA - N-nitrosoethylphenylamine
NDELA - N-nitrosodie thanolamine
NMELA - N-nitrosomonoethanolamine
NDPLA - N-nitrosodipropanolamine
NDiPiA - N-nitrosodiisopropanolamine
NNN - N-nitrosornicotine
NNK - 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone
NAT - N-nitrosoanatabine
NMU - N-nitrosomethylurea
NEU - N-nitrosoethylurea
NPU - N-nitrosopropylurea
NMUT - N-nitrosomethylurethane
NPRO - N-nitrosoproline
NHPRO - N-nitrosohydroxyproline
NSAR - N-nitrososarcosine
NMPABAO - N-nitroso-N-methyl-p-aminobenzoic acid octyl ester

Appendix C. Smoke Analysis from 19F1A Trainer Bilge Fire Compartment

CENTER FOR FIRE RESEARCH: Smoke Analysis			FILE ID:	TO2	TR3	TS1
SAMPLE DATE: 7 November, 1989			TRAP ID:	TO	TR	TS
GOAL: Component Identification			VOLUME:	10 (L)	UKN	UKN
Name of component	MWT	RTave	PROB	PROB	PROB	
Acetaldehyde	44	1.61		78	78	
Ethanol	46	2.31		60	60	
2-Propanone	58	2.75		76	76	
Methane, dichloro-	84	3.62				81
Oxirane, 2,3-dimethyl-	72	6.23		52		
Benzene	78	8.64				89
Acetic acid	60	8.96	83			
Cyclopentanone	84	13.89				79
Hexanal	100	14.12		42		29
Heptanal	114	17.20		60		
Oxirane, 2,3-dimethyl-	72	17.34				20
.alpha.-Pinene	136	18.15		93		
Octanal	128	19.63		57		
Nonanal	142	21.63		86		
			blank	1.5 min sample	3.0 min sample	

Analysis by Indoor Air Quality Unit
Center for Building Technology
National Institute of Standards and Technology

MWT = Molecular weight of species

RTave = Retention time, minutes, on gas chromatograph (GC) column

Prob = Probability of occurrence based on computer recognition of mass peaks found by mass spectrometer analysis of the separated G.C. fraction

NOTE: Sensitivity of this technique to benzene is 2.5 nanograms. Gas flow through the sample tubes ("traps") was 200 cc/min. Since benzene was found in the 600 cc sample, but not in the 300 cc sample, the benzene content was at least 2.5 nanograms/600 cc (4.2 micrograms/m³), but not as much as 2.5 nanograms/300 cc (8.4 micrograms/m³). The pinene probably was carried by wind from a grove of pine trees located south of the trainer facility. The four aliphatic aldehydes were probably carried on the same gust of wind (not present in the 3 minute sample or the blank).

Appendix C. (continued)

CENTER FOR FIRE RESEARCH: Smoke Analysis				FILE ID:	IS01	IS02	IS03	IS04	IS05	IS06
SAMPLE DATE: 26 October, 1989				TRAP ID:	TK	TL	TN	IO	TR	TS
GOAL: Component Identification				VOLUME:	1.5L	1L	1UKN	1UKN	1UKN	1UKN
Name of component	MWT	RTave	PROB	PROB	PROB	PROB	PROB	PROB	PROB	PROB
Acetaldehyde	44	1.61	78	70	70			78	78	
1,3-Butadiyne	50	2.02	89							
Ethanol	46	2.31	70					60	60	
2-Propanol	56	2.56	52							
2-Propanone	58	2.75	67	76	76			76	76	
2-Propanol, 2-methyl-	74	3.45		60						
Ethanamine, N-methyl-	59	3.43	52		83					
Methane, dichloro-	84	3.62	88	79					81	
1,3-Cyclopentadiene	66	3.73	89							
Methane, nitro-	61	4.60	84							
2-Butanone	72	6.03	52							
Oxirane, 2,3-dimethyl-	72	6.23						52		
1,4-Cyclohexadiene	80	7.86	67							
1,3-Cyclopentadiene, 1-methyl-	80	8.07	89							
Benzene	78	8.64	92	92	92				89	
Acetic acid	60	8.96								
2-Pentanone	86	9.68		70						
Pentanal	86	10.18	73	63	86					
Heptane	100	10.36	86		86					
Oxirane, 2-methyl-2-(1-methylethyl)-	100	11.72		70						
Benzene, methyl-	92	12.61	96	93	96					
Cyclopentanone	84	13.89							79	
Hexanal	100	14.12						42	29	
Octane	114	14.19	65		93					
Ethene, tetrachloro-	164	14.53	86							
Benzene, chloro-	112	15.66	95	95	95					
Benzene, ethyl-	106	16.19	95	97	89					
Benzene, 1,3 & 1,4-dimethyl-	106	16.45	97	95	95					
Benzene, ethynyl-	102	16.70	93	93						
3-Heptanone	114	16.99	89	89						
Bicyclo[4.2.0]octa-1,3,5-triene	104	17.17	94	93	96					
Heptanal	114	17.20						60		
Benzene, 1,2-dimethyl-	106	17.25	95	95						
Oxirane, 2,3-dimethyl-	72	17.34							20	
Nonane	128	17.58	95	95	95					
.alpha.-Pinene	136	18.15						93		
Benzene, (1-methylethyl)-	120	18.27	95	95						
Hexanal, 2-ethyl-	128	19.15	94	71						
Pentane, 2,2,3,4-tetramethyl-	128	19.19		63						
Decane, 2,5,6-trimethyl-	184	19.35	78	78						
Benzene, 1-ethyl-3-methyl-	120	19.43	95	94						
Octanal	128	19.63						57		
Benzene, (1-methylethenyl)-	118	20.05	94	95						
Furan, 2-pentyl-	138	20.30	59	53						
Decane	142	20.50	87	89						
Nonane, 3,7-dimethyl-	156	21.56	60	60						
Nonanal	142	21.63						65		
Phenol, 2,6-bis(1,1-dimethylethyl)-4-met	220	33.28		85	86					

The first three "prob" columns are analysis of samples taken at the 21C12 firefighter trainer, Groton, Connecticut. No blank was taken since the sample train was destroyed by radiant heating. Most of the species indicated are probably products of overheated Tygon tubing. The last three columns are the same data as page C1.

BIBLIOGRAPHIC DATA SHEET

1. PUBLICATION OR REPORT NUMBER
NISTIR 4318
2. PERFORMING ORGANIZATION REPORT NUMBER
3. PUBLICATION DATE
May 1990

4. TITLE AND SUBTITLE

Exhaust Gas Analysis for Harmful Species: 19FlA Fire Fighting Trainer at
Mayport, Florida

5. AUTHOR(S)

Robert S. Levine and Kevin Greenaugh

6. PERFORMING ORGANIZATION (IF JOINT OR OTHER THAN NIST, SEE INSTRUCTIONS)

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MD 20899

7. CONTRACT/GRANT NUMBER

8. TYPE OF REPORT AND PERIOD COVERED

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)

Naval Training Systems Center
Orlando, Florida 32826-3224

10. SUPPLEMENTARY NOTES

☐ DOCUMENT DESCRIBES A COMPUTER PROGRAM; SF-185, FIPS SOFTWARE SUMMARY, IS ATTACHED.

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

Gas sampling and subsequent analysis was carried out in a prototype Navy Firefighter Trainer to determine whether toxic species would be released to the environment by the Trainer. The Trainer uses propane gas for fires, and makes artificial smoke by vaporizing the smoke agent, butylated triphenyl phosphate, in hot air. There was concern that the smoke agent would react with the propane flame to form toxic products.

No evidence of reaction or toxic species beyond those to be expected from a clean propane flame was found.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

Toxic products; smoke; training devices; smoke production; chemical analysis; gas analysis

13. AVAILABILITY

☒	UNLIMITED
☐	FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NATIONAL TECHNICAL INFORMATION SERVICE (NTIS).
☐	ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, DC 20402.
☒	ORDER FROM NATIONAL TECHNICAL INFORMATION SERVICE (NTIS), SPRINGFIELD, VA 22161.

14. NUMBER OF PRINTED PAGES

24

15. PRICE

A02

